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Assessment of Trace Metal Disturbances in Healthcare Workers Exposed to Low Dose Ionizing Radiations in a Tertiary Care Hospital

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ABSTRACT

Objective: To determine the effects of ionizing radiations on trace metal levels in healthcare workers exposed to occupational radiation in a tertiary care health facility.

Study Design: Comparative cross-sectional study.

Place and Duration of Study: Department of Chemical Pathology & Endocrinology, Armed Forces Institute of Pathology, Rawalpindi Pakistan, in collaboration with the Department of Radiology, Combined Military Hospital, Rawalpindi Pakistan, from Apr to Oct 2021.

Methodology: Healthcare workers (n=45) exposed to occupational radiations were compared with an equal number of Controls in a tertiary care health facility for their trace metal levels. An atomic absorption spectrophotometer (AAS) was used to measure serum zinc (Zn) and copper (Cu) levels. A calorimetric technique was used to measure serum iron (Fe) levels.

Results: Mean serum Copper (9.54±2.52 µmol/l) and Zinc (11.78±1.90 µmol/l) concentrations of the Risk-Group were significantly lower than their respective Control-Groups (Copper: 14.76±3.13 µmol/l and Zinc: 14.67±3.01 µmol/l). At the same time, mean serum Iron levels in the Exposed-Group (17.55±3.88 µmol/l) were significantly (p<0.001) higher than the Control-Group (14.41±4.23 µmol). The duration of radiation exposure was inversely proportional to serum Copper (*p-value* 0.002) and serum Zinc (p<0.001) concentrations, which is statistically significant. At the same time, serum iron level (*p-value* 0.001) and TIBC (p-value 0.003) increased proportionately with increasing duration exposure, which was also statistically significant.

Conclusion: Low-dose ionizing radiation exposure led to a significant decrease in serum Copper and Zinc levels, whereas an increase in serum Iron levels was noted. There was an association of trace metal disturbances with increasing radiation exposure.

Keywords: Healthcare workers, Low-dose ionizing radiation exposure Ionizing radiation, Trace metals.

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INTRODUCTION

Radiation exposure due to radiotherapy, diagnostic, interventional radiology or nuclear accidents can cause multiple tissue injuries, severely affecting health quality.[1] Radiation-induced injury is a complex event. There is a diverse spectrum of tissue injuries caused by radiation exposure due to varying sensitivities of the tissues to radiation.[2,3] The tissues with a high rate of cell proliferation are more sensitive to radiation and, thus, are more susceptible to injury, especially in the case of the gastrointestinal tract.[4]

Trace elements play a pivotal role in human physiological and metabolic processes.[5] These processes can be affected by the slightest variation in the optimum concentrations of these metal elements, leading to several diseases, such as metabolic disorders, sleep disturbances, dermatological problems, psychiatric disorders and even cancer.[6,7] Over the past few decades, there has been rapid development in medical imaging technologies, which led to improvement in diagnosis of disease, examination of internal organs and therapeutic interventions. However, extensive medical imaging technologies and comprehensive applications have exposed radiation workers to potential effects. Recent studies with occupational radiation exposure of radiologists, radiology technologists and nuclear power plant staff revealed various toxic effects of radiation on the human body, such as disturbance in immunological parameters and increased cancer incidence.[8,9]

It has been well-recognized that trace elements like Zinc, Copper and Iron are important in maintaining normal physiology. Several reports on the

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biological effects of high-dose ionizing radiations are known. However, there needs to be more information and unknown factors on the effects of low-dose ionizing radiation. Low-dose ionizing radiations considerably affected the hair and nails of radiology staff with deficient Zinc and Copper levels.[10] Achieving comprehensive information in this area requires extensive research. This study aimed to demonstrate the potential effects of chronic low-dose ionizing radiations on trace metal levels in radiation workers exposed to occupational radiation and its associated health hazards.

METHODOLOGY

The comparative cross-sectional study was conducted at the Department of Chemical Pathology, AFIP, Rawalpindi Pakistan, from April to October 2021 after getting ethical approval (FC-CHP-25/READ-IRB/21/654) from the Institutional Review Board of AFIP, Rawalpindi Pakistan. The sample size was calculated using WHO sample size determination software, taking sigma as 0.1495, µ1 as 0.768 and µ2 as .872.[4]

Inclusion Criteria: Male medical radiographers aged 20–60 years, exposed to radiation for six months or more, were selected for the study. An equal number of age-matched healthy Controls not exposed to the radiation) were selected from the community.

Exclusion Criteria: Individuals with chronic diseases or individuals on copper, zinc and iron supplementation were excluded from this study**.**

Ninety male participants were selected for the study, out of which 45(50%) were the healthy Controls through a non-probability consecutive sampling technique. They were divided into an Exposed-Group comprised of medical radiographers exposed to radiation from multiple sources with a minimum of 6 months of radiation exposure (Computed tomography scan, Nuclear medicine, X-ray) and a Control-Group comprised of healthy participants without radiation exposure. The Exposed-Group were medical radiographers exposed to radiation for six months or more. An equal number of age and lifestyle-matched Controls were selected. Personal badge film dosimetry record was noted using permissible limits that are less than 1.67 millisieverts (mSv) per month or less than 20 mSv per year as per Pakistan Nuclear Regulatory Authority (PNRA) regulations PAK-904.7 Reference interval of Zinc was taken as 12–18µmol/l, Copper was 10-22µmol/l and Iron was 8.5-28.9 µmol/l.8 Venous blood using an aseptic technique was collected in 5ml plain serum tubes. The serum was separated by centrifugation at 3500 revolutions per minute (RPM) for 5 minutes and stored at-20oC for subsequent analysis. Sample collection and serum separation were carried out in a free environment.

Copper and Zinc were analyzed using Flame Atomic Absorption Spectrophotometry (Agilent Technologies 200 series). The colourimetric technique measured serum Iron levels and TIBC on Siemens ADVIA 1800 fully automated Chemistry Analyzer.

Data were analyzed using the Statistical Package for Social Science (SPSS v 23.0) program. Results were expressed as mean and standard deviation. Descriptive statistics and an independent sample t-test were applied to compare the mean values of study groups. One-way analyses of variance (ANOVA) were applied to evaluate the variation within the Exposed Group. Statistical tests were considered to be significant at $p \leq 0.05$.

RESULTS

A total of ninety male subjects were enrolled, of which 45 were exposed to radiation, and 45 were not exposed to radiation. Out of 45 exposed subjects, 18 worked in the X-ray (Radiography) Section (40%), eight worked in the Fluoroscopy section (17.77%), 9 in the CT Scan section (20%), and 10 worked in the Nuclear Medicine Department (23.23%) as shown in Figure. Personal badge film dosimetry record showed radiation exposure well within permissible limits as per PNRA regulations.

NUMBER OF PARTICIPANTS EXPOSED TO RADIATION

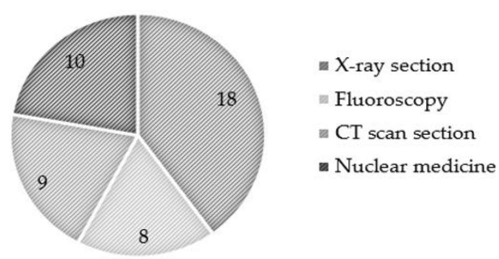

Figure: Participants from different sections of Radiology Department and Nuclear Medicine (n=45)

The mean age of the Exposed Group was 32.3±7.55 years, and the Control Group was 29.91±6.64 years. Mean serum Copper (9.54±2.52 µmol/l) and Zinc (11.78±1.90 µmol/l) concentrations of the exposed Group were significantly lower than their respective Control Groups (Copper: 14.76±3.13 µmol/l and Zinc:

14.67±3.01 µmol/l). At the same time, the mean serum Iron in the exposed Group (17.55±3.88 µmol/l) was significantly (p<0.001) higher than the Control Group (14.41±4.23 µmol/l). Mean serum TIBC in the exposed and Control Groups were 57.67±4.23 and 63.92±7.59, respectively (p<0.001), as shown in Table-I. Duration of radiation exposure was inversely proportional to serum Copper and serum Zinc concentrations, which was statistically significant (p<0.05), as shown in Table-II. In comparison, serum Iron and TIBC increased proportionately with increasing duration of radiation exposure, which was also significant (p<0.05).

Table-I: Effects of Ionizing Radiation on Biochemical Parameters in Exposed vs. Non-Exposed Group (n=90)

Biochemical Parameter	Exposed (Mean±SD) n=45	Non Exposed (Mean±SD) n=45	*p*-value
Copper (µmol/l)	9.54±2.52	14.76±3.13	<0.001
Zinc (µmol/l)	11.78±1.90	14.67±3.01	<0.001
Iron (µmol/l)	17.55±3.88	14.41±4.32	<0.001
Hemoglobin (g/dl)	14.89±1.04	15.06±1.01	0.459
Total iron binding capacity	57.67±4.23	63.92±7.59	<0.001

Inter-Group comparison (Post hoc analysis) is shown in Table-III. Our results showed a statistical difference between Groups one vs three and one vs four concerning copper. Similarly, Group 1 vs 4 showed significant differences for zinc, iron and haemoglobin.

Table-II: Variation in Concentration of Biochemical Parameters within the Exposed-Group on the basis of duration of Exposure (n=45)

Parameters	Group-1 < 5y years of exposure (n= 17)	Group-2 5–10 years of exposure (n=14)	Group-3 10–15 years of exposure (n=6)	Group-4 >15 years of exposure (n=8)	*p*-value
Copper (µmol/l)	10.91±2.50	9.83±2.03	7.63±1.68	7.56±1.91	0.002
Zinc (µmol/l)	12.98±1.57	11.82±1.75	10.83±1.38	9.86±1.24	<0.001
Iron (µmol/l)	15.05±2.43	18.02±3.45	18.80±3.67	21.12±4.24	0.001
Hb (g/dl)	15.31±0.88	14.71±0.79	15.25±1.45	14.06 ± 1.01	0.024
TIBC (µmol/l)	57.66±3.32	57.57±4.31	53.13±4.72	61.27±2.09	0.003

Hemoglobin, Hb; Total iron binding capacity, TIBC.

Table III: Inter-Group comparison of Exposed Group (Post Hoc analysis) (n=45)

Group Comparison	Group-1 Vs. Group-2	Group-2 Vs. Group-3	Group-1 Vs. Group-3	Group-2 Vs. Group-4	Group-1 Vs. Group-4	Group-3 Vs. Group-4
Copper (µmol/l)	0.322	0.429	0.030	0.317	0.012	1.00
Zinc (µmol/l)	0.180	0.571	0.029	0.035	<0.001	0.661
Iron (µmol/l)	0.075	0.962	0.093	0.161	0.001	0.563
Hb (g/dl)	0.324	0.672	0.999	0.437	0.022	0.122
TIBC (µmol/l)	1.00	0.082	0.063	0.125	0.120	0.001

DISCUSSION

Trace metal elements play a pivotal role in various biological processes of living systems.[11] Some of the important functions of these metal elements are a defence against free radicals and preservation of the integrity and health of cell membranes. Trace elements form complexes such as metalloenzymes with different bio-ligands playing a unique role in response to oxidative stress.[12]

Increased oxidative stress is the major cause of damage due to radiation. Previous studies have shown that trace elements play an essential role in human oxidative stress and thus may be related to radiation-induced damage.[13] The concentrations of these metal elements in the body are low and within a very narrow reference interval to maintain normal physiology, so a slight alteration in their concentrations may lead to important changes in the physiological processes. Continuous low levels can have a significant negative impact on the human body.[14,15]

This study was conducted to highlight the effects of low-dose ionizing radiations on the concentration of some trace elements such as Copper, Zinc and Iron in radiation workers. In our study, serum levels of Copper, Zinc and Iron were measured and compared with the Control Group to demonstrate the possible effects of low-dose ionizing radiations. Serum levels of Copper and Zinc of the exposed Group were low, whereas serum Iron level was raised compared to Controls. Our study also concluded that the duration of the radiation had an inverse relation with serum Copper and Zinc and a direct relation with Iron. This disturbance could be associated with chronic exposure to ionizing radiations on trace elements.

The earlier studies substantiate the results of the current study. One study showed a decrease in the concentration of Copper and Zinc and an increase in the concentration of Iron in the blood of radiographers as compared to the Control Group, which is in accordance with the results of our study.[16] Another study showed a significant reduction in serum Copper concentration in the case Group compared to the Control Group, which is also consistent with our results.[17] One more study showed that the concentration of Copper in the case Group was significantly higher than in the Control Group, which is not in agreement with the results of the Copperrrent study.[18] A previous study showed the changes in trace elements in radiology staff. It showed that Zinc was higher in the Control Group than the exposed Group, and there was no significant difference in Copper concentration between the two Groups.[19]

Medical radiographers are regularly exposed to radiation and, therefore, are at a high risk of radiation-induced harmful effects.[20] A more comprehensive study and regular monitoring of trace elements among individuals working in a radiation environment is required to establish harmful effects on the human body.

CONCLUSION

Low-dose ionizing radiation exposure may significantly decrease serum Copper and Zinc levels, whereas an increase in serum Iron levels was noted. There is an association of trace metal disturbances with increasing radiation exposure.

Conflict of Interest: None.

Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

AAG: & MUM: Data acquisition, data analysis, drafting the manuscript, critical review, approval of the final version to be published.

ZHH: & MA: Data acquisition, concept, study design, approval of the final version to be published.

MBK: & SIK: Critical review, data interpretation, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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